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(54) Electroluminescent display devices

(57) A thin-film electroluminescent display device comprising a glass substrate (11), a transparent conductor (12), a phosphor layer (15) between two insulating layers (13, 14), an opaque back conductor (17), includes a layer (16) of a material that interferes with the incoming light, thus eliminating the problem of reflection when the display is viewed under conditions of high ambient illumination, e.g. direct sunlight. The material used for the light-interfering layer is lanthanum hexaboride, chromium oxide, titanium oxide, vanadium oxide or boron carbide.

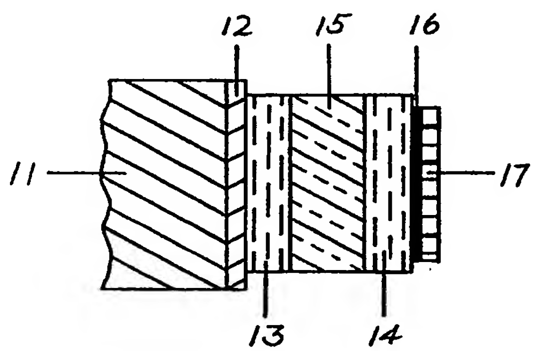

fig. 3

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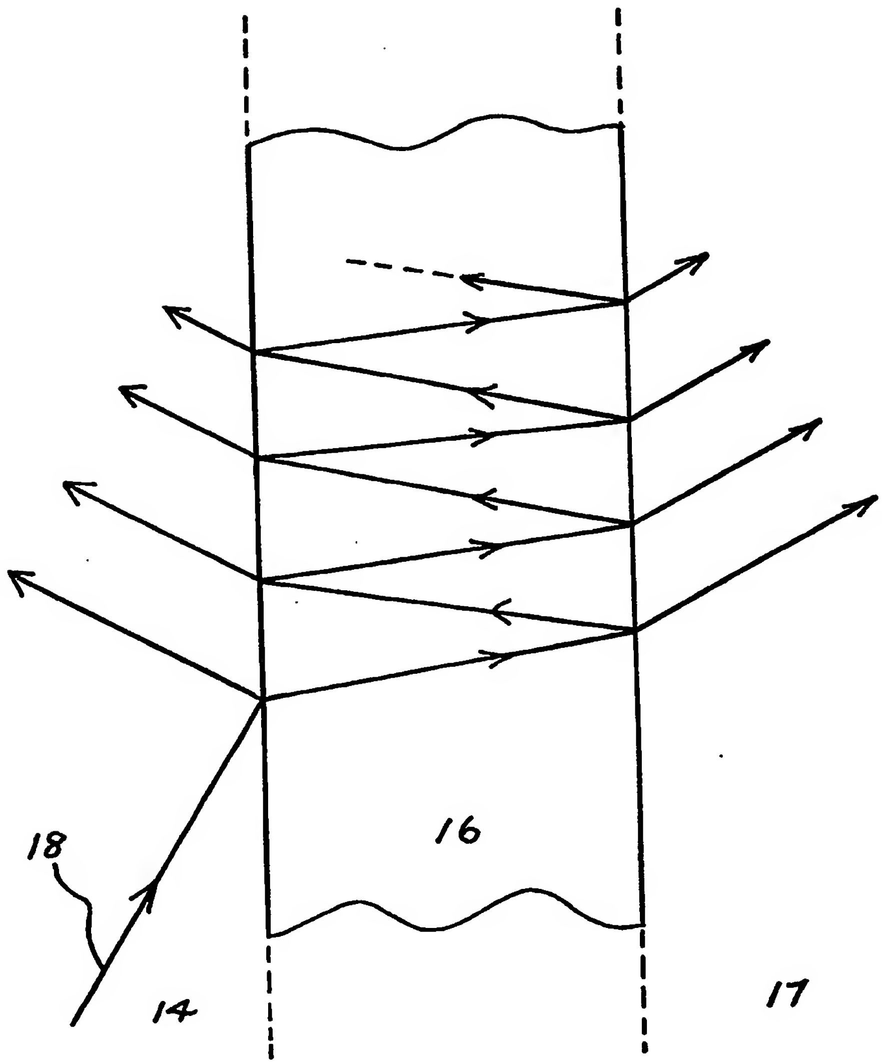

fig. 1

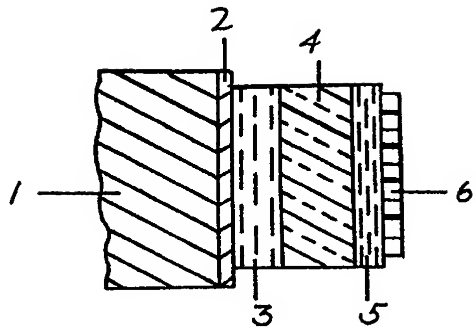

fig. 2

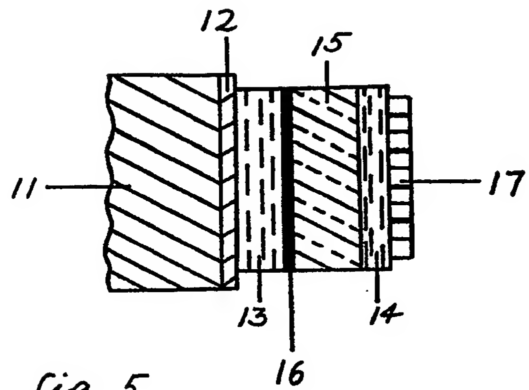

fig. 5

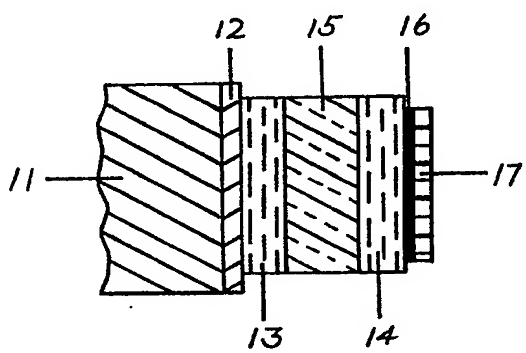

fig. 3

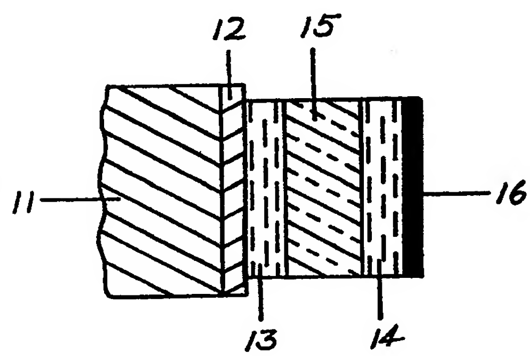

fig. 6

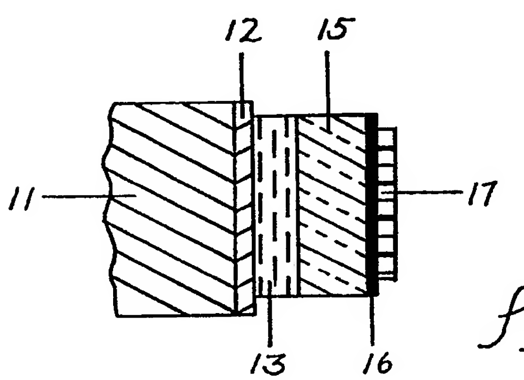

fig. 4

SPECIFICATION
Electroluminescent display devices

Conventional thin-film electroluminescent displays are multilayer devices consisting of a glass substrate, a transparent conductor, a phosphor layer between two insulating layers, and an opaque back conductor, generally aluminium. Light is produced in the phosphor layer by the application of an AC voltage to the two conductive layers and emission occurs as a result of the excitation of activator ions by injected electrons.

A major concern in using any type of display for example in an aircraft instrument panel, is the ability of the viewer to read the display under conditions of high ambient illumination, e.g. direct sunlight. Under such conditions, the opaque back conductor which has high metallic reflectance reflects more light than the electroluminescent element emits, and so the display is rendered ineffective.

There have been many attempts to provide a phosphor-emitting display that operates with a high contrast ratio under high ambient illumination conditions with a minimum sacrifice of emission brightness.

Solutions to the problem include the incorporation of a dark material into the glass or of a dark dye into the phosphor dielectric layer; these methods proved unsatisfactory because they result in the reduction of the intensity of the emitted light as well as of the reflected light. An overlay of a perforated opaque layer on the viewing side of the glass substrate of the device has been proposed, but this is unsatisfactory because it restricts the viewing angle.

The incorporation of a particular light-absorbing layer on the viewing side of the back conductor was suggested in U.S. Patent No. 3 560 784. The absorbing materials have an index of refraction substantially equal to that of the phosphor layer and provide a contiguous and continuous transition at the interface of the phosphor layer and the light-absorbing layer, thus minimising the reflection of light on this interface. The light-absorbing layer is substantially transparent at the interface and a gradually increasing concentration of light-absorbing material is introduced within the dark layer toward the back layer. This method has the disadvantages of requiring elaborate material and process control as well as complex apparatus to create this tapered concentration of absorptive materials within a thin film layer.

It has now been found that the problem of reflection when the display is viewed under conditions of high ambient illumination can be eliminated by employing a layer that is capable of combining an interference effect with the ability to absorb the light traversing through, that is, induced absorption. This layer may conveniently be referred to as a "black" layer.

A thin-film electroluminescent display device according to the invention comprises a glass viewing surface, a transparent conductor, a light-emitting phosphor layer between two insulators, and an opaque back conductor, and includes a layer of material that interferes with incoming light to minimise reflection and improve contrast on the viewing surface.

The invention is now described with reference to the accompanying drawings; in which:—

Figure 1 is a simplified diagrammatic view showing the passage of incident light between an insulating layer and the back conductor in an electroluminescent display device;

Figure 2 is an enlarged cross-sectional view of a conventional electroluminescent display device;

Figure 3 is an enlarged cross-sectional view of the preferred embodiment of this invention;

Figure 4 is an enlarged cross-sectional view of another embodiment of this invention;

Figure 5 is an enlarged cross-sectional view of still another embodiment of this invention; and,

Figure 6 is an enlarged cross-sectional view of another embodiment of this invention.

Figure 2 shows a conventional display that consists of a glass substrate 1, a transparent conductor 2, a transparent insulator 3, a phosphor layer 4, an insulating layer 5, and an aluminium conductor 6. The aluminium layer has a high metallic reflection which, when used under high ambient lighting conditions such as direct sunlight, reflects more light toward the observer than the electroluminescent element emits and thus renders the display ineffective.

Figure 3 illustrates the preferred device of the present invention. The first layer 12 deposited directly on the glass substrate 11 is a transparent electrically conductive coating. This first layer is generally a composition of tin oxide and indium oxide. Glass substrates with this coating are available commercially, for example Nesatron glass.

The second layer 13 and the fourth layer 14 are insulators required to prevent electrical breakdown. Such materials are yttrium oxide (Y_2O_3), aluminium oxide (Al_2O_3), tantalum oxide (Ta_2O_5), or the like are suitable for these layers.

The third layer 15 is the phosphor which is the source of light. Suitable materials include, but are not limited to, ZnS:Mn(orange), CaS:Ce(Green), SrS:Ce(blue), ZnS:Te,Mn(red), and the like.

The fifth layer 1 is the black layer to improve contrast. It is a hard film of a semi-conducting highly dispersive material. It has a suitable optical dispersion in the visible spectrum to create the desired induced absorption between the dielectric layer 14 and the back metal electrode layer 17 of the thin-film electroluminescent display. Examples of suitable materials include, but are not limited to, lanthanum hexaboride (LaB_6), chromium oxide (C_2O_3), titanium oxide (TiO), vanadium oxide (V_2O_3), and boron carbide (BC_4). These materials are by nature refractory ceramics and as such have an intrinsic stability against short circuit and blow-out.

The final layer 17 is the back conductor, usually aluminium.

As illustrated in Figure 1, the incoming light 18 is made to reflect between the two boundaries of the black layer 16 so that each time it traverses through the black layer a portion is absorbed; in other words, the light is trapped by the black layer. In addition, very little light is reflected from the black layer, so it is an effective antireflection material.

The black layer 16 of this invention is preferably incorporated in front of the back electrode 17, as in Figure 3. It is, however, within the scope of this invention to place it in other locations in an electroluminescent display device, for example as a replacement for insulating layer 14 (Figure 4), between insulation layer 13 and the phosphor 15 (Figure 5), or as an electrode to replace the back electrode 17 (Figure 6).

Although the thicknesses of the layers are not critical, in general the coating 12 on the glass is about 200 to 1,000Å, and preferably about 500Å; the phosphor layer 15 is about 1,000 to 10,000Å, and preferably about 4,000Å, between two films of electric insulation 13 and 14, each about 500 to 5,000Å, and preferably 2,000Å each; the aluminium electrode 17 is about 200 to 10,000Å, and preferably about 1,000Å. The thickness of the layer 16 of this invention depends upon the material selected. It may be selected to give the desired interference effect and is generally between 50 and 1000Å thick. The layer is generally of substantially uniform composition across its thickness. When a layer of LaB_6 is used, it may be about 200 to 800Å, and preferably about 250Å; a layer of TiO is generally about 400 to 1,000Å thick, and preferably about 500Å; a layer of V_2O_3 is generally about 300 to 1,000Å thick, and preferably about 350Å; a layer of Cr_2O_3 is generally about 200 to 1,000Å thick and preferably about 50 to 500Å, and preferably about 100Å. The small amount of residual reflection may appear green, magenta gold, depending upon the optical thickness of the black layer or the position of the quarter wave peaks in the visible spectrum. Thus the colour can be varied by changing the thickness of the layer.

Experiments were carried out to illustrate the effectiveness of various materials as the black layer in electroluminescent (EL) display devices. When used with an aluminium electrode, the material was deposited between it and the insulating layer 14. The displays were tested with a Sylvania SG—77 Sun Gun, and the results are tabulated below:

Material	TiO	LaB_6	V_2O_3	Cr_2O_3	BC_4
Veeco Quartz Monitor Thickness	<500Å	<350Å	<350Å	200Å	110Å
Visual Appearance in Reflection	metallic yellow	metallic blue	metallic purple	metallic silver	metallic
Visual Appearance in Transmission	absorbing grey	absorbing grey	absorbing grey	absorbing brown	brownish grey
Electric Resistivity	100 to <3,000 ohm/sq.	100 to 3,000 ohm/sq.	>20 megaohm/sq.	>100 megaohm/sq.	>100 megaohm per sq.
El Test without Al Electrode	(a)*	>100 ft.-lambert	—	—	—
El Test with Al Electrode	(a)*	>100 ft.-lambert	(a)	—	(a)

*(a) = works satisfactorily

From the above it can be seen that, if the resistivity is sufficiently low, as in the case of TiO and LaB_6, the material can be used directly as the back surface electrode.

In each case the black layer improved the contrast to the point where the gun could be placed 14.5 cm in front of the display (a third of the distance used to simulate sunlight, and therefore, nine times the brightness) without obliterating the glow of the display.

The use of this light-interfering black layer reduces to a minimum (about one per cent) the reflectance from both interfaces, the one between the black layer and the adjacent layer toward the viewer and the one between the black layer and the back metal conductor. In addition, there is no sacrifice of emission brightness, brightness levels of more than one thousand foot-lamberts being obtained, in contrast with about one hundred foot-lamberts for typical television CRTs. Moreover, lifetimes in excess of 40,000 hours were achieved.

The products of this invention can be made by any known and convenient means. Preferably, however, such thin-film electroluminescent display devices are produced by vacuum deposition, such as electron beam evaporation techniques, resulting in the production of large area substrates with high resolutions. Generally the entire structure is sealed to prevent contamination from the external environment.

The display devices of this invention are suitable for use as electroluminescent panels, e.g. numerical displays or other types of information display panels such as used in aircraft instrument panels, computer terminals, word processors, and the like, in the form of vertical scale displays, round dial displays, illuminated reticles, matrix displays and so forth.

CLAIMS

1. A thin-film electroluminescent display device comprising a glass comprising a glass viewing surface, a transparent conductor, a light-emitting phosphor layer between two insulators, and an opaque back conductor, and which includes a layer of material that interferes with incoming light to minimise reflection and improve contrast on the viewing surface.

2. A device according to claim 1, wherein the light-interfering layer is a hard film of a semi-conducting highly dispersive material.

3. The device according to claim 1 or claim 2, wherein the light-interfering material is selected from lanthanum hexaboride, chromium oxide, titanium oxide, vanadium oxide and boron carbide.

4. A device according to any preceding claim wherein the light-interfering layer is located between the back conductor and the insulating layer adjacent the back conductor.

5. A device according to any of claims 1 to 3, wherein the light-interfering layer is located between the phosphor and the insulator adjacent the transparent conductor.

6. A device according to claim 1 wherein the light-interfering layer is located between the phosphor and the opaque conductor, and serves as an insulating layer.

7. The device of claim 1 wherein the light-interfering layer serves as the opaque back conductor.

8. A thin-film electroluminescent display device substantially as herein described with reference to, and as shown in, the accompanying drawings.

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